Ecological correlations of nocturnal bird assemblages in Malaysian Borneo

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Malaysian Borneo supports a rich assemblage of five nightbird families, comprising 13 species of owl, six of frogmouth and four of nightjar. Many nightbirds are dependent on forest habitats, but their ecology remains poorly known. Our study examined the relationships between nocturnal bird species richness and environmental variables based on citizen science data—bird records collected in Malaysian Borneo from 2000–2012. The environmental variables were altitude, distance to waterbodies, distance to human settlements, and land cover type, generated from geographic information system (GIS) data. For 18 species found in three land cover types, the Shannon-Wiener H diversity value was highest in primary forest, followed by fallow agricultural land and secondary forest. Except for the distance to human settlements, our generalised linear model (GLM) showed significant positive relationships between species richness and distance to waterbodies, as well as altitude. However, the land cover type of each site did not significantly influence species richness. Our findings suggest that primary forests remain a relatively important habitat for nocturnal bird communities in Borneo, but it is likely that some species may be able to adapt to and exploit secondary habitats, although the extent of this warrants future study.

INTRODUCTION

As in the case of diurnal birds of prey, many nocturnal bird species are top predators. Food niche overlaps are likely to occur among nocturnal and diurnal birds, implying that changes in population size and diversity of the former may directly affect those of the latter and *vice versa* (Bosakowski & Smith 1992, Gliwicz 2008). Regardless of their ecological importance, the status of many species remains poorly known and there is limited information on their ecology. This is particularly true in the Indo-Malayan region, which supports a high diversity of nocturnal birds, especially owls Strigidae and frogmouths Podargidae (Holyoak 1999, König *et al*. 1999, Marks *et al*. 1999, Wells 1999). One reason for the lack of ecological information on nocturnal birds is the difficulty of studying them given the problems of low visibility and observer safety, coupled with the elusive behaviour of many species (Sheldon *et al*. 2001) and the often difficult access to habitats such as tropical forests.

Along with the increase in forest disturbance (Achard *et al*. 2002), there have been varying degrees of change to animal communities, depending on forest condition (Berry *et al*. 2010, Edwards *et al*. 2010, Sberze *et al*. 2010). Some avian species are able to persist in secondary forest despite the general absence of large trees (Barlow *et al*. 2006, Yap *et al*. 2007). However, most studies have focused primarily on diurnal birds. Whether nocturnal birds can persist in disturbed forests awaits further investigation. A comparison of nocturnal bird species found in old-growth and secondary forest in the Brazilian Amazon indicated that several species occurred in both forest types whereas certain species favoured either the undisturbed or disturbed areas (Sberze *et al*. 2010). Given that many animal species can persist in secondary forests (Chazdon *et al*. 2009), the role of these forests in sustaining biodiversity will become increasingly important. Furthermore, the occurrence of these species in disturbed habitats has a bearing on the ecological integrity of the habitat, given that their loss can have a cascade effect on the biotic communities within a particular ecosystem (Sekercioglu 2010).

In Malaysian Borneo 23 nightbird species are known to occur, consisting of 13 owls, six frogmouths and four nightjars. One is classified as Vulnerable and six are Near Threatened (Table 1). The Dulit Frogmouth *Batrachostomus harterti* and Bornean Frogmouth *B. mixtus* are endemic to Borneo's mountains whereas Rajah Scops Owl *Otus brookii* is endemic to the montane habitats of Borneo and Sumatra. To date, there have been relatively few published studies of Borneo's nightbirds (e.g. Sheldon *et al*. 1983, Mann 1991, Jenkins *et al*. 1996, Sheldon *et al*. 2001, King 2002, Biun *et*

al. 2006, Yong 2006, Hamid *et al*. 2008, Yong & King 2010), and none has examined the relationships between bird communities and environmental factors. Although it has been claimed that the loss of old-growth forest in the Indo-Malayan region has caused declines in certain owl species (Marcot 1995), no information is available on how these nocturnal birds respond to the increasing fragmentation of primary forest and the growth of secondary forest.

With the increased rate of natural forest conversion and the unknown impacts of such ecological disturbance on nocturnal birds, our study aimed to examine the environmental variables that determined nocturnal bird species richness in Malaysian Borneo based on observational data collected from 2000–2012 in primary forests, secondary forests and fallow agricultural lands.

METHODS

Primary and secondary data
Location records of all resident nightbirds from 2000–2012 from several sites in Malaysian Borneo were compiled from the published citizen science data, including *Suara Enggang* (with a compilation of verified local bird records) as well as those from the Malaysian Nature Society Bird i-Witness database. All records in that database were reviewed and verified by the Malaysian Nature Society Bird Conservation Council and Records Committee. Records include individual sightings, active nest encounters and calls (when their identification and location had been verified). During the preparation of this paper, the Bird i-Witness database was integrated with the eBird database (www.eBird.org).

Derivation of environmental variables from GIS datasets
The environmental characteristics of the locations in which nightbirds were recorded were derived using a GIS package. Based on habitat characteristics described in the literature, sightings and previous studies of nocturnal birds (Kavanagh *et al*. 1995, Sberze *et al*. 2010), we identified four environmental variables that potentially affect nocturnal bird distributions: altitude, distance to waterbodies, including streams and rivers, distance to human settlements, and land cover type. For altitude, the 30 m-resolution Digital Elevation Model from the Shuttle Radar Topographic Mission (SRTM-DEM) was acquired. This was used to map river networks based on flow accumulation grid analysis (Chang 2003). The distance of each record to waterbodies was calculated in ArcGIS (ESRI, Redlands, USA). After obtaining human settlement data from the *Digital chart of the world* (DCW) database in shape file

format, the distance to human settlements was also calculated with the same module.

Three land cover types—primary forest, secondary forest and fallow agricultural land—were identified in the study. The locations of bird records were first examined by overlaying them with protected areas and forest reserves in Sabah and Sarawak, the two states in Malaysian Borneo. The classification of forest types (primary or secondary) where birds were recorded was based on land cover type maps of Sabah (Osman *et al.* 2012) and Sarawak (Kamlun *et al.* 2012) which had been produced from supervised classification of Landsat5 images. Primary forests were identified as mainly protected areas and forest reserves that have not been logged, while secondary forests were identified as forests subjected to a 30-year logging rotation. Due to the small numbers involved, all other land cover types were grouped together and categorised as fallow agricultural land, defined as either bare ground or land that had been used for cultivation. We excluded records that were made in one oil palm plantation, as its intensive planting system cannot be categorised as fallow agricultural land. After verifying the locations, attribute values of the four variables were extracted for statistical analysis.

Data analysis

We analysed the data based on both site-level (48 individual sites) and land cover type-level (as defined above). To combine the bird counts from different visits, we summed the number of bird observations made from each visit to the same site. In terms of species numbers, we counted each species only once for each site, irrespective of its abundance. Owing to the non-random nature of the data, we used the bootstrap re-sampling method (random type; $n = 1,000$) to estimate species richness and relative abundance (estimates and confident limits) per site. To compare species richness

between sites with different land cover types, we performed an unbalanced ANOVA. We also calculated the bootstrap diversity statistics (Shannon-Wiener H) and confidence interval for each land cover type ($n = 1,000$) (Krebs 1999). To compute the Shannon-Wiener index, we included the number of individuals and species at each site.

We performed a generalised linear model (GLM) to examine the relationships between species richness and environmental variables. We used quasi-Poisson distribution and log-link function to fit the data (response variable = species richness; $n = 48$ sites). Five explanatory variables were included in our models: altitude; distance to nearest waterbodies; distance to nearest settlements; sampling effort (i.e. visit frequency to each site); land cover type. To simplify computation, land cover type was fitted as an absorption factor. To improve the representativeness of the model prediction, the number of observations for each species was used as a weighting factor in the model. We followed Dormann *et al.* (2013) to examine if there was collinearity between explanatory variables with correlation coefficient, $|r| > 0.7$ implying that model estimation and prediction can be distorted due to collinearity between the variables. In this study, none of the explanatory variables had $r > 0.7$. Hence, we included all explanatory variables in the model. All analyses were conducted via GenStat version 12.0 (VSN International, Hemel Hempstead, UK).

RESULTS AND DISCUSSION

Overall, a total of 228 individuals (bootstrap mean of bird abundance per site = 4.86 ± 1.08 SE, 95% CI: 3.09–7.16) from 18 species (bootstrap mean of species per site = 1.91 ± 0.21 SE, 95% CI: 1.51–2.36) were recorded (Table 1).

Table 1. Altitudinal range (m) and distribution of nightbird records in Malaysian Borneo, by state and land cover type.
= Vulnerable, * = Near Threatened, " = listed as possibly extinct in Borneo (Myers 2009), † = recent fieldwork has found a number of new sites for the species (Low *et al.* 2014, J. C. B. Harris *in litt.*), suggesting a wider distribution.

Species	No. of records by state		No. of records by land cover type			Altitudinal range (m)
	Sabah	Sarawak	Primary forest	Secondary forest	Fallow agricultural land	
FAMILY TYTONIDAE						
Barn Owl *Tyta alba*	0	0	0	0	0	NA
Eastern Grass Owl *Tyta (capensis) langimembris*	0	0	0	0	0	NA
Oriental Bay Owl *Phodilus badius*	4	2	1	4	1	15–1,332
FAMILY STRIGIDAE						
Reddish Scops Owl *Otus rufescens* *	3	15	15	3	0	19–894
Mountain Scops Owl *Otus spilacepholus*	3	3	6	0	0	544–1,332
Mantanani Scops Owl *Otus mantananensis* *	6	0	6	0	0	NA
Sunda Scops Owl *Otus lempiji*	1	9	6	0	4	13–894
Rajah Scops Owl *Otus braakii* "	0	0	0	0	0	NA
Barred Eagle Owl *Buba sumatranus*	1	13	10	1	3	7–1,862
Buffy Fish Owl *Ketupa ketupu*	32	4	29	2	5	8–227
Collared Owlet *Glaucidium bradiei*	3	1	4	0	0	544–1,677
Brown Boobook *Ninax scutulata*	10	33	30	10	3	15–1,792
Brown Wood Owl *Strix leptagrammico*	10	3	12	1	0	8–248
FAMILY PODARGIDAE						
Large Frogmouth *Botrochastamus ouritus* *	0	1	1	0	0	NA
Gould's Frogmouth *Botrochostomus stellotus* *	2	0	2	0	0	17–220
Blyth's Frogmouth *Botrochostomus (jovensis) affinis*	0	3	2	0	1	15–19
Sunda Frogmouth *Botrochostomus cornutus*	1	0	1	0	0	NA
Bornean Frogmouth *Batrachostomus mixtus* *†	0	2	2	0	0	1,520–1,862
Dulit Frogmouth *Batrachostamus harterti* *†	0	0	0	0	0	NA
FAMILY CAPRIMULGIDAE						
Large-tailed Nightjar *Caprimulgus macrurus*	10	36	31	7	8	7–129
Bonaparte's Nightjar *Coprimulgus cancretus* #	0	0	0	0	0	NA
Savanna Nightjar *Coprimulgus offinis*	0	1	1	0	0	NA
FAMILY EUROSTOPODINAE						
Malay Eared Nightjar *Lyncarnis temminckii*	2	14	14	1	1	10–1,074
	88	140	173	29	26	

Regardless of site, the Shannon-Wiener H diversity value was highest in primary forest (bootstrap mean of 3.52 ± 0.03 SE; 95% CI: 3.46–3.58), followed by fallow agricultural land (bootstrap mean of 2.56 ± 0.09 SE; 95% CI: 2.36–2.71) and secondary forest (bootstrap mean of 1.98 ± 0.11 SE; 95% CI: 1.74–2.18). As in previous studies (Kavanagh & Bamkin 1995, Brooks *et al.* 2002, Lambert & Collar 2002, Aratrakorn *et al.* 2006), our results indicated that primary forest habitat remains the most important for nightbirds given their diversity in that habitat. This may be because many owls require tree cavities for nesting that are likely to be found only in old-growth forests (Newton 1994). Nonetheless, this does not necessarily mean that conservation measures should not be implemented in secondary forest and fallow agricultural land (Sberze *et al.* 2010, Sekercioglu 2010, Azhar *et al.* 2011).

The results of our GLM showed significant positive relationships between species richness and three environmental variables—altitude, distance to waterbodies and sampling effort (Table 2). More nocturnal bird species were detected at sites located far from waterbodies (Wald statistic = 14.82, P < 0.001). This was not unexpected, as few nightbirds are dependent on riparian habitats when foraging, although some, such as Buffy Fish Owl *Ketupa ketupu*, may rely on aquatic resources (e.g. fish and riparian habitats) whereas nightjars—e.g. Bonaparte's Nightjar *C. concretus* (Phillipps & Phillipps 2011) and Malay Eared Nightjar *Lyncornis temminckii* (Holyoak 2001)—may prefer to hunt for insects over streams close to forest. It is possible that running streams may attenuate bird calls, making detection more difficult, which results in a higher detection rate away from waterbodies. However, as described in Myers (2009), the foraging habitat of the above nightjar species may not be limited to waterbodies, but also include clearings in forest.

Referring to Table 1, both land use type and altitudinal range for most records accorded well with those described in the literature (Smythies & Davison 1999, Holyoak 2001, Myers 2009, Phillipps & Phillipps 2011), except for Sunda Scops Owl *O. lempiji*, which was not recorded, as expected, from secondary forest habitat (Phillipps & Phillipps 2011) and was found in agricultural land. Reddish Scops Owl *O. rufescens* is associated with primary forest (Meijaard *et al.* 2005, Phillipps & Phillipps 2011) and the majority of the records (83%) were obtained there, with few found in secondary forest (Myers 2009). Although the overall number of records of Podargidae species remained low, it is worth highlighting that most of these records (89%) were obtained from primary forest, as were the records of Strigidae and Eurostopodidae.

Table 2. Results of the GLM of species occurrence against environmental variables.

Explanatory variable	Parameter estimate	Wald statistic	P value
Altitude	0.0000946	8.49	0.004
Distance to waterbodies	0.0000545	14.82	< 0.001
Distance to settlements	−0.0000046	0.004	0.889
Sampling effort	0.03828	110.24	< 0.001

Nocturnal bird species richness increased with altitude (Wald statistic = 8.49, P = 0.004). However, we suspect that such results may be mainly because undisturbed forest habitats are more often found at higher altitude. Indeed, highland specialists including Mountain Scops Owl *O. spilocephalus*, Collared Owlet *Glaucidium brodiei* and Bornean Frogmouth were found mainly in primary forest (Table 1). In Borneo, many lowlands are heavily populated or cultivated (Kamlun *et al.* 2012, Osman *et al.* 2012), resulting in the widespread loss and fragmentation of forest habitat important to nocturnal birds. Conversely, there are a number of nightbird species that remain largely confined to lowlands, particularly Reddish Scops Owl and Buffy Fish Owl, despite the literature indicating that they may be found at higher altitudes (Robson 2008, Myers 2009). Similarly, although Brown Wood Owl *Strix leptogrammica*

may be found at higher altitudes (Robson 2008), most of the records in this study were obtained from lowlands. Hence, the loss and disturbance of lowland habitats may have an even greater impact on these species. However, the associations between species occurrence, habitat preference and altitude remain poorly known and deserve further study, as highlighted in Kavanagh *et al.* (1995).

We found that species richness was not significantly influenced by distance to human settlements. Furthermore, when analysing the data by study sites, there was no significant difference in species richness between different land cover types (F = 0.25, *d.f.* = 2, P = 0.779). One possible explanation is that many nocturnal birds originating from forests are using disturbed habitats, although the relative importance of altered habitats is unclear. This may indeed be an important implication of forest disturbance to nocturnal bird assemblages. Owing to forest disturbance, species originally dependent on forests may have been commuting to secondary forests (Sekercioglu 2010) in search of prey species supported by these areas. For some species, broad dietary and foraging behaviour may allow them to disperse into secondary habitats. For example, nightjars may use more open, disturbed habitats for foraging whilst the abundance of small mammals in plantations may draw owls into cultivated land (Marks *et al.* 1999) and the availability of low vegetated branches may provide roost sites for frogmouths (Myers 2009). Owls such as Brown Wood Owl seem to be tolerant of human development (Hassan *et al.* 2013), although whether these birds are able to breed successfully in disturbed habitat remains unclear. Disturbed forests may only serve as suboptimal habitats for species forced to use such areas. Certain species, particularly those dependent on primary forests (e.g. Reddish Scops Owl: Meijaard *et al.* 2005), may still be vulnerable to forest conversion due to specific habitat requirements. For example, many owls are cavity nesters and breeding opportunities are limited by the availability of tree holes, particularly in logged forests where many large trees have been extracted.

Our model also indicated that sampling effort contributed to the variations in species richness (Wald statistic = 110.24, P < 0.001). This is to be expected due to the non-random nature of the data obtained from different visits. For this reason we took time variation into account by including sampling effort as an explanatory variable when running the models. Despite the data used in this study being based on records over 13 years, the sample size of 228 individuals was rather low. This is believed to be mainly due to the very few observations made at night (rather than at daytime roosts), coupled with the difficulties in accessing the relevant habitats. Certain species may be less or non-vocal at some times of the year, e.g. the non-breeding period, and hence were undetected (e.g. Barn Owl *Tyto alba* and Eastern Grass Owl *T. longimembris*). Even with such limitations of using citizen science data, this study demonstrated the importance of having amateur or nonprofessional scientists for long-term ecological monitoring work.

Given the increasing conversion of natural forests to cultivation or logging concessions, long-term studies on the population dynamics of nocturnal birds in relation to habitat change and fragmentation are needed. While many recent studies have looked into the conservation value of disturbed habitats such as secondary forests (Edwards *et al.* 2009, Berry *et al.* 2010, Edwards *et al.* 2010), and many of these focused on birds, none has examined nocturnal bird assemblages in any detail. It remains to be investigated how owl, nightjar and frogmouth species and assemblages will respond to logging and habitat fragmentation, even though some level of resilience has been demonstrated in a few species (Sberze *et al.* 2010).

Our findings not only add to the current limited knowledge of nightbirds in the tropics, but also contribute towards the understanding and conservation of these birds and the habitats which support the associated biotic communities. With the increase in literacy and research linkages in the region, the political and

linguistic limitations (Corlett 2011) that restrict the dissemination of ecological information on tropical nightbirds, if any, are expected to be resolved in the future. Until more ecological studies are done consideration should be given to the conservation of both primary and secondary forests due to their roles as optimal and suboptimal habitats, respectively, for most Bornean nocturnal birds. Ensuring the viability of this group of birds will certainly facilitate a better understanding of nightbird ecology through ecological research, which in turn will aid in conserving an ecosystem that comprises interrelated diurnal and nocturnal communities.

ACKNOWLEDGEMENTS

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